University of Glasgow

HIGH FREQUENCY COMMUNICATION SYSTEMS

Lecture 4

Hasan T Abbas & Qammer H Abbasi

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LECTURE OUTLINE

- Transmission Lines Theory & Analysis
- The Smith Chart
- Load Mismatching
- The Magic of Quarter-wave Transformer

- A technique to bridge the gap between basic circuit analysis and electromagnetic fields theory
  - Lots of similaritites and analogies
- Commonly used to design microwave devices and circuits

- In wave scattering problems, we place the co-ordinate system at the boundary
- In transmission lines, we use the two different lines as the boundary
- For open problems, the load is considered to be at infinity.

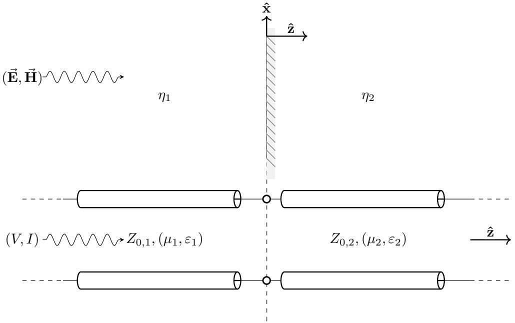
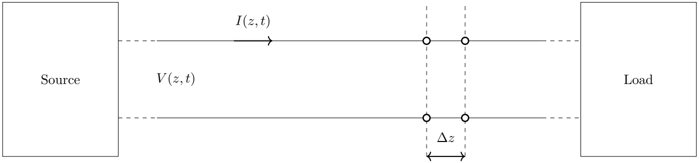
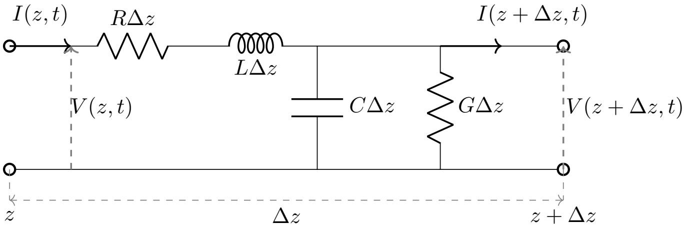


Figure 1: The analogy between wave problems and transmission lines.

TL Theory	EM Field Theory
$V_1 = V_0 e^{-j\gamma_1 z}\left(1 + \Gamma_L e^{j2\gamma_1 z}\right)$	$E_{x,1} = E_0 e^{-jk_1 z}\left(1 + \Gamma e^{j2k_1 z}\right)$
$I_1 = \frac{V_0}{Z_{0,1}} e^{-j\gamma_1 z}\left(1 + \Gamma_L e^{j2\gamma_1 z}\right)$	$H_{x,1} = \frac{E_0}{\eta_0} e^{-jk_1 z}\left(1 + \Gamma e^{j2k_1 z}\right)$
$\Gamma_L = \frac{Z_L - Z_{0,1}}{Z_L + Z_{0,1}} = \frac{Z_{0,2} - Z_{0,1}}{Z_{0,2} + Z_{0,1}}$	$\Gamma = \frac{\eta_2 - \eta_1}{\eta_2 + \eta_1}$
$V_2 = T V_0 e^{-j\gamma_2 z}$	$E_{x,2} = T E_0 e^{-jk_2 z}$
$I_2 = T \frac{V_0}{Z_{0,2}} e^{-j\gamma_2 z}$	$H_{x,2} = T \frac{E_0}{\eta_2} e^{-jk_2 z}$
$T = \frac{2Z_{0,2}}{Z_{0,2} + Z_{0,1}}$	$T = \frac{2\eta_2}{\eta_2 + \eta_1}$

- For a transmission line, we use a distributed circuit approach
  - Energy stored in the magnetic field $\rightarrow L$
  - Energy stored in the electric field $\rightarrow C$
  - Conductive losses $\rightarrow R$
  - Dielectric losses $\rightarrow G$
- All the circuit elements are expressed per unit length
- We can express the voltage and current at any given point z and time t.


Source
$I(z,t)$
$V(z,t)$
Δz
Load


$I(z,t)$
$R\Delta z$
$L\Delta z$
$I(z+\Delta z,t)$
$V(z,t)$
$C\Delta z$
$G\Delta z$
$V(z+\Delta z,t)$
z
Δz
$z+\Delta z$

- Solving the electric circuit leads to a second order differential equation
- Analogous to the wave equation
  - Hence the analogies between voltage V and electric field $\vec{\mathbf{E}}$

$$\left\{\frac{\partial^2}{\partial z^2} - [(R + j\omega L)(G + j\omega C)]\right\} V(z,t) = 0$$

The solution is of the type:

$$V(z) = V_{+}\mathrm{e}^{-\gamma z} + V_{-}\mathrm{e}^{+\gamma z}$$

where the propagation constant $\gamma = \sqrt{(R + j\omega L)(G + j\omega C)}$. For a lossless case $R = G = 0$.

EQUIVALENT CIRCUITS - TERMINATED LOAD